Title: Solar Lab Beginnings at Harding University

Author: Jennifer Warnert

Abstract:

Harding University engineering students, as part of a partnership with a Christian school in Peltan, Haiti, are making plans to design a system to provide electricity to the school for lighting for adult night classes. This report focuses on the solar portion of that project in conjunction with the designs of solar energy applications at HUT and at the University itself. Overall, much progress has been made and a lot has been learned, but there is still a lot of work to be done. This report serves as the documentation for what has already been done and what still needs to be done, with a summary of research done to help those who work on the project next.

Introduction:

Harding University's engineering and professional counseling departments are part of a partnership, called Ansanm (which means "together" in Haitian Creole), with a Christian elementary school in Peltan Haiti. This allows for collaboration between the local Haitians and Harding students and faculty allowing students to benefit educationally from service learning while working with the Haitians to sustainably improve their quality of life [1]. Sometime in the near future, the school would like to start providing adult night classes for vocational training in order to benefit the community and help those in the community to have a sustainable income through the trades they learn. In order to do this, the school would need some form of electricity to light the building at night. A $3000 grant was received by the class from ASME to be used by June 2012 for this endeavor. Possible solutions that have been explored for this electricity need are solar energy, a merry-go-round generator system, and a hybrid of the two. The plan was to design a system to be installed in Haiti on the mission trip there in May taken by Harding University's Engineering Service Project Class. This report focuses on the solar energy component of work done by the class.

Up until this project, Harding University had very little solar energy equipment. Thus, this project also presented a strong educational opportunity for students to learn about solar energy at Harding for years to come. Harding also has a program called Harding University at Tahkodah (HUT), which is a missionary training village [1]. In the fall of 2012, HUT will be hosting the Global Mission Experience [2], with one of the experiences being focused on alternative energy. This also presents an opportunity for and gives importance to the solar energy work done. There is also currently a water delivery system at HUT that was set up by a previous Harding University group that was originally going to be run by bike-generated power. This project may present an opportunity to use either the merry-go-round or solar energy to power the pump there as well.

The original objectives for the Solar Energy Lab were as follows:

1. Economical Solutions
2. Design for cost-free electricity at school in Haiti.
3. Design a system to help educate Harding students (and others) about solar energy.
4. Effectively generate enough power to get the water delivery system at HUT working.

These were not all accomplished this year, but the groundwork for them was completed and all things done toward the solar project were done with these objectives in mind.

The possible outcomes and deliverables that were planned for this project were the following:

1. A relatively small system at Harding that demonstrates how solar energy works.
2. Solar power for the water delivery system at HUT.
3. A system designed for Haiti.
4. Solar panels incorporated on the roof of the science building.

These also were not all accomplished, but progress has been made toward the goals. One purpose of this report is to document the progress that was made and the work that was done so that future Engineering Service Project classes can build from it and complete the project.

Part of the way through the project, through communicating with the Haitian school's director, Richard Rodney, we found out that the solar energy would not be implemented this year at the school due to security issues. Richard believes that security is a top priority before anything else is put in place at the school because of jealousy and vandalism issues. Thus, much of the class' effort was put into designing perimeter walls for the school to keep people out after hours. The current plan is to implement the electrification of the school on the trip in 2013 instead.

The community partners of this project were HUT and the Haitian School, and the stakeholders were Richard Wells (the course instructor), and Harding University. The team members were Jennifer Warnert (the team leader), Brandon Huber, and Mitch Maynard.

Methods:

General:

The first thing done was research about solar energy in order to get an idea of how it works. Some things that were researched were types of solar panels, the components of a solar energy system, cost of solar panels, and how to build solar panels from scratch. Also, lighting needs for various types of spaces were researched.

Next, the Haitian school's needs were assessed. Calculations were done for how much light they might need and how much electricity it would take. These were based on information found online about lighting standards, known dimensions of the school, and observations of what works for lighting here and in Nicaragua. Thought was also put into deciding which type of light bulbs to use: incandescent, compact fluorescent or led bulbs.

Then, it was decided that the class would build solar panels from solar cells found on ebay. A major help in this process was the website on which one man, Michael Davis, explains how he built solar panels. This site is included in the works cited [4]. The purpose of this was mostly educational, as we decided that it would be better to bring professional-quality solar panels to Haiti for durability and sustainability. However, the plan was to simulate a system much like the one that would be set up in Haiti. The solar panels made could be useful at HUT for running the water pump.

Solar System Building:

The first step in building solar panels was to come up with a plan of the materials needed. The following is a list of what we anticipated needing:

1. Solar cells (we purchased reject cells from ebay and sorted out the good ones.)
2. Tabbing wire (used to attach the solar cells together in series and parallel. This has solder on it already.)
3. Flux pen (To help attach the tabs to the solar cells. Came with solar cells on ebay.)
4. Soldering iron (Harding has several)
5. Junction boxes (used as a junction to plug into the solar panels.)
6. Batteries (Deep Cycle, Trojan brand batteries are the type available in Haiti)
7. Charge Controller (This controls the charging of the batteries from the solar panels.)
8. Inverter (This converts the DC power to AC to be used by the lights.)
9. Light Fixtures (ceramic ones were bought from Lowe's.)
10. Light bulbs (purchased on Amazon.com)
11. A switch and box for it (purchased on Amazon.com)
12. Wiring (There is still a question as to how much we need.)
13. Plexiglass (to cover the solar cells on the solar panel, known as acrylic at Lowe's)
14. Wood (to build a frame for each solar panel)
15. Screws (to build frame with)
16. Tools to build the frame (also supplied by Harding)
17. Caulk (to seal the solar panel, and to adhere the solar cells to the frame)
18. White paint (to seal the wood from water. White was chosen because it will not absorb heat as much, and heat can damage the solar cells.)
19. Shottky diodes (low power loss diodes to keep current from flowing backwards in the solar panel.)
20. A plug (to plug into the inverter from the lights.)

Next, the supplies were ordered and some designing was done. The current design for the solar panels needs some work. We were mostly working from the instructions on Michael Davis' website. More work will need to be done to get a good, sustainable design. The general solar system design is shown in figure 1 below.

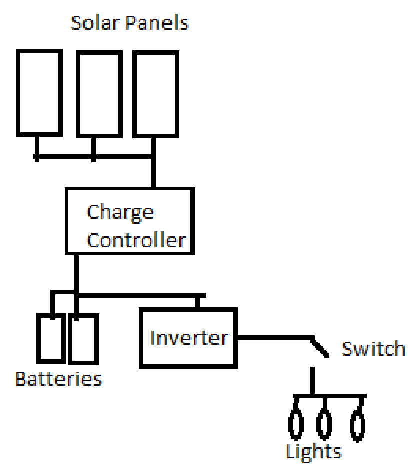

Figure 1: A diagram of a simple solar energy system. Electricity flows from the solar panels into the charge controller which regulates the charging of the batteries until they are full. Then, when electricity is needed and the switch is closed, it flows from the batteries to the inverter where it gets converted from DC to AC and to the lights, turning them on.

Once the solar cells arrived, some of them were sorted by how well they appeared they would perform. The nearly perfect were set aside to be used. The whole cells with cracks were put in another pile, and the cells with just a few chips were put in another pile. Cells with significant damage, such as being broken in half, were put in yet another pile. Some testing was done on the voltage and current of these cells with a simple multimeter. With the cell placed under a lamp for more intense light, it should have a voltage of about 0.5 V regardless of the size. The tabs on the top of the cell are one terminal and the tabs (or white squares if the back is not yet tabbed) are the other terminal. The size of the cell determines the current through it, and the cell in a panel that produces the least current limits the current and the power of the entire solar panel. Thus, it is important that cells of the same size/current are used to manufacture a panel for greatest efficiency. Ideally, before building the solar panels, each cell should have its voltage and current checked under a controlled light to ensure quality and efficiency. It is important to be extremely careful with the cells throughout this entire process in order to keep them from breaking as they are very fragile. Anyone doing this is likely to break at least two even when being careful.

After testing a few of the cells, we began soldering tabs onto the back. The tabbing wire has solder already on it, so additional solder is not needed. However, one of the two soldering methods we discovered does involve adding a small amount of solder. The first method involves putting tiny pieces of solder on the white squares on the back of the solar cells, placing the tabbing on top of them, and pressing down with a chisel-tipped soldering iron until the solder has melted enough to bond tabbing wire with the cell. The other method we used, involves first using the flux pen on the little squares to help the tabbing wire bond with the solar cell. Then, the tabbing wire is placed on the cell and the chisel-tipped soldering iron is pressed down gently on the tabbing where it needs to bond with the cell until the solder on it has melted enough to bond the two. Either way, one may want to use a pliers or something to hold down the tabbing while soldering so it doesn't move around. More experimentation is needed to determine which

soldering method (whether one of these or another) is the best way to attach the tabbing in such a way that it stays on. It is important to keep in mind that these solar cells will be moved around a bit and then glued to the panel's frame. The tabbing wire must stay attached through this process. Another important note is that the tabbing wires on the back should hang off the side of the solar cell a little more than a quarter inch on the opposite side of the front tabbing overhang so that the cells can later be attached in series as explained later.

The next step is to build the frame for the solar panels. Things to keep in mind include:

1. Each cell is 3" by 6"
2. 36 cells in series are needed to make a panel that will charge a single 12 V battery
3. There should be at least a quarter inch between each cell. (This assumption could be changed based on further research and other factors.)

   (The first three determine the dimensions of the panel.)

4. Ventilation holes will be needed.
5. White paint will not absorb as much heat and is thus better for the solar cells that can be damaged by heat.
6. Plexiglass is difficult to cut to the right size.
7. Screws hold stronger than nails, and can be more easily disassembled.
8. Solar cells will be attached with caulking.

Once the wooden frame is constructed, the solar cells can be glued to the panel with caulking. A small amount of caulk in the center is best so that the cells don't break from the rigidity of attaching the whole surface [4]. The tabbing from the cells will need to overlap in such a way that they can be connected in series by simple soldering. It is probably best to space them about a quarter inch apart. Figure 2 illustrates soldering in series vs. soldering the cells in parallel.

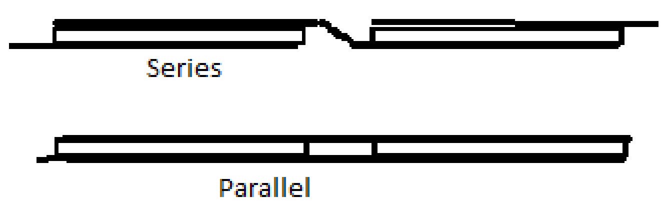

Figure 2: When soldering cells in series, voltages add, while soldering cells in parallel, currents add. Most of the time, solar cells are connected in series to reach the desired voltage. This is done by connecting the overhanging tab from the top of one to the overhanging tab from the bottom of the next. This is similar to stacking batteries on top of each other to connect them in series except for solar cells, the top needs to be exposed to light, so wires are used to connect tops and bottoms instead of just stacking.

Once all of the cells are attached to the frame, they can be soldered together. The most simple way to do this is to put a small amount of flux on the top overhang of one cell, make sure the

bottom overhang of the next cell overlaps it, and press down lightly with the soldering iron until a bond is made. More information about this can be easily found on the internet.

After the solar cells are all attached in series, additional wiring will be needed to attach everything in the junction boxes and to plug into the charge controller. At this point, the solar panel should be tested to make sure everything works before attaching the protective plexiglass to the top of the panel.

Results and Discussion:

Much information was gathered and learned in researching. It was found that there are four main types of solar cells used in solar panels. The first is monocrystalline, which is more efficient and expensive, and is better in high-light. The second is polycrystalline, which also works better in high-light conditions, but is less efficient and less expensive. Another is amorphous, which is also known as thin film. This type works well in low light and is cheaper, but takes up more space. Finally, the fourth technology is hybrid, which is a combination of monocrystalline and amorphous. It has high efficiency in high and low-light conditions. Monocrystalline or polycrystalline will probably work best for the system in Haiti.

Research was also done in regard to how solar cells work. It was found that photovoltaic solar cells are made of doped silicon. They are similar to a flat diode. When light hits the silicon, it transfers some energy to the free electrons in the cell, making them move, and thus causing a current to flow.

Some information was also found out about charge controllers. Essentially, a charge controller functions as a buffer between a power source and batteries. It regulates the charging of the batteries and protects them from overcharging or draining too far. Some charge controllers can only do one of these though, so it is important to read the documentation on any charge controller considered. The main thing to consider on charge controllers is the amount of power they can handle. Some will only handle around 100 W, which is not enough for electrification of Haiti. It can also be noted that solar charge controllers cannot be used for other applications such as mechanical generators and alternators. Solar charge controllers are only designed to handle a small range of voltages that are typical for solar panels, so they are not good for use with generators that can have significant voltage spikes and often output larger voltages than do solar panels.

In regard to the cost of solar panels, it was estimated that making solar panels for the project would cost at most $450 and buying them would cost at most $540. These estimates are based on $3 per Watt (high estimate, $2-$3 per Watt can be expected) for already made solar panels and 180 W worth of panels needed, which will be explained later. It was decided that the extra durability and sustainability was worth the extra cost for Haiti, especially since the system must be easily maintained by local Haitians. However, it was decided that solar panels would be built

for the educational value and to possibly be put in place at HUT to power the water delivery system.

The three types of light bulbs considered were incandescent, compact fluorescent, and led bulbs. Compact fluorescent (CFL) is the current choice due to the much greater efficiency compared to incandescent and the greater availability compared to led bulbs. However, led bulbs are more efficient than CFLs, so if prices decrease or if they can be determined to be more durable, they may be considered as another option. Another advantage of led bulbs is that they may be usable with DC power, so they may eliminate the need for an inverter. All calculations for power needs were done based on using CFLs.

As for lighting needs, things are still a little cloudy. The U.S. standard for the amount of light needed to read is 30 foot candles (fc). However, calculations done with this show that lighting the school would require at least 40 light bulbs. That may not sound like a lot, but the building has outer dimensions of only 24' by 48'. The lighting needs were recalculated with 20 fc using the simple lumen method illustrated in equation 1.

$$total\ lumens = (\#of\ fc) * 2 * Area \qquad (1)$$

To light a quarter of the one room school, which is about 11 by 23 ft., with 20 fc, it would take about 10,120 lumens. Each CFL bulb supplies about 800 lumens, so 12-13 bulbs would be needed. For the sake of easily arranging them, the count of 12 bulbs was used for the estimate. CFLs that supply 800 lumens require about 15 W per bulb, so that's 360 W needed continuously. If that is multiplied by the four hours a day that the lights will be needed, the estimate becomes 1440 Watt-hours per day. Since there are eight hours of sun per day, (1440/8=180), the solar panels must supply at least 180 W of energy. However, for such a small space, 12 bulbs still seems like a lot, especially since it was observed that they have maybe 2-4 CFL bulbs for about that same amount of space or larger in Nicaragua. A pattern for arrangement of the bulbs is still needed as is the estimate for the amount of wire needed. It may be useful to come up with some sort of inexpensive reflective mechanism (maybe made with aluminum foil) that would help redirect some of the light that would otherwise go toward the high ceiling. Before deciding the placement of the lights, it may be useful to know the positioning of the rafters in the ceiling of the building.

Conclusion:

Overall, a lot was learned in the course of this project so far, but there is still a lot to be done to make this solar energy lab what it could be. Some of the next steps include finishing building the solar panels and possibly installing them at HUT, formulating a detailed design for the system to be installed in Haiti, and developing a more educational setup for the portion of the solar lab at Harding.

Specifically, it would be beneficial if measurements of ceiling height and positioning of ceiling rafters could be taken by the group that goes in May 2012. Building the solar panels will mostly just take time, but some learning is also involved in the process, especially soldering techniques and hands-on experience with solar cells. Other options for lighting the school in Haiti may also be explored, such as task lighting. One idea that has been brought up is a set of portable solar lights that are just hung outside to charge during the day and then brought inside to be used by individuals to light their areas at night during class. This idea may deserve more research before final decisions are made on the design of the system.

Works Cited

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